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How is mechanical work partitioned between surface energy and heat during earthquake ruptures?

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Recent studies of exhumed faults have shown that fault zones formed during many successive earthquakes are characterized by an extremely thin principal slip zone (≤ 5 mm) located within an ultracataclasite fault core (0.1-1 m) embedded in a highly fractured damage zone. These geological observations agree with laboratory experiments on the frictional response of fault gouge at large slip amplitudes suggesting that slip is extremely localized in a narrow slipping zone within the gouge layer. The earthquake energy balance should be formulated to account for energy absorbed in gouge production in such a complex fault zone model.

The earthquake energy budget is usually expressed by the partitioning of elastic strain energy into radiated energy, frictional work and the fracture energy consumed as a rupture area expands. In the classical slip-weakening model, the dividing line between frictional work and fracture energy is assumed to be the constant sliding or residual stress value, and it is assumed that all the frictional work goes into heat. We present evidence from recent earthquakes that this assumed division between heat and fracture energy is not true for large earthquakes. We have inferred the traction evolution on a fault plane for several recent earthquakes and we have used the traction versus slip curves to measure the breakdown work at each point of the fault, defined as the excess of work over the minimum level of stress reached during slip at each point. Our definition of breakdown work is equivalent to fracture energy defined as above in the classic slip weakening model, but is applicable to complicated, empirically determined traction-slip curves with dynamic fault weakening and restrengthening. Our breakdown work estimates computed for extended earthquake models tend to be significantly larger than geological estimates of surface energy from the Punchbowl fault [Chester et al., 2005] and the San Andreas at Ft. Tejon [Wilson et al., 2005]. This suggests that breakdown work is expended both in heat and gouge formation/evolution during dynamic slip episodes, and that the boundary between heat and surface energy in stress-vs.-slip diagrams probably does not lie along a horizontal line at the minimum level of stress. Thus, "seismological fracture energy" is not identical to the energy used to create fractures during earthquakes.